# EvTEC EVALUATION PLAN
# for
# ULTRA-URBAN
# STORMWATER TECHNOLOGIES

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# ABSTRACT

This plan describes the nature and scope of an environmental evaluation of ultra-urban stormwater control devices.

Comprehensive stormwater regulations, space limitations, hardened infrastructure, high urban land values, and the increase in urban runoff pollutant loads over the last decade have spurred the development of a new class of products and technologies. These non-traditional methods of capturing runoff contaminants before they reach surface and ground waters have been labeled in many circles as “ultra-urban” technologies.

The stormwater systems products to be evaluated should be market-ready. A number of the stormwater agencies have expressed a desire and, in some cases, a need, to have baseline environmental data about the effectiveness and removal efficiencies of these types of proprietary stormwater control devices. The agencies need this information to make some initial references about the effectiveness of installing these types of technologies to reduce the pollutant impact on local watersheds and ecosystems.

The primary objective of the Stormwater Ultra-Urban Evaluation Plan is to perform well-defined field and laboratory testing that will provide baseline environmental data about the effectiveness and removal efficiency of each individual technology held to the same testing protocol. These data will be summarized in Verification Reports for each technology to be distributed to federal, state, and local environmental regulators and agencies. The goal is to provide potential users and purchasers of these technologies with this information so that they can make informed decisions about using these systems on their infrastructure.

The evaluation will be overseen and coordinated by the Washington State Department of Transportation and the Environmental Technology Evaluation Center (EvTEC), a program of the Civil Engineering Research Foundation (CERF), the research and technology transfer arm of the American Society of Civil Engineers (ASCE). The evaluation process used by EvTEC is described in this plan.

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| Bert Bowen | Washington Department of Transportation |
| Rick Brush | Montgomery County, MD |
| Patricia Cazenas | Federal Highway Administration |
| Robert Chandler | City of Seattle |
| Stan Ciuba | Washington Department of Ecology |
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| Richard Field | US EPA, NRMRL |
| Rod Frederick | US EPA, Office of Water |
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## ACRONYMS

| | |
|---|---|
| ASCE | American Society of Civil Engineers |
| BMP | Best Management Practice |
| BOD | biological oxygen demand |
| CBOD | carbonaceous biological oxygen demand |
| CDS | Continuous Deflective Separation |
| SERF | Civil Engineering Research Foundation |
| CFS | cubic feet/second |
| COD | chemical oxygen demand |
| CSO | combined sewer overflow |
| DOT | Department of Transportation |
| Ecology | Washington State Department of Ecology |
| EPA | US Environmental Protection Agency |
| ETV | Environmental Technology Verification Program |
| EvTEC | Environmental Technology Evaluation Center |
| HRM | Highway Runoff Manual |
| KCRTS | King County Runoff Time Series |
| LCC | life cycle costs |
| *m*g/ℓ | micrograms per liter |
| mg/ℓ | milligrams per liter |
| MS | matrix spike |
| MSD | matrix spike duplicate |
| O&M | operation and maintenance |
| PSD | particle size distribution |
| QA/QC | quality assurance/quality control |
| RPD | relative percent difference |
| SBUH | Santa Barbara Urban Hydrograph |
| SP | soluble phosphorus |
| TKN | total Kjeldahl nitrogen |
| TOC | total organic carbon |

# 1.0 OBJECTIVES AND GOALS

## 1.1 INTRODUCTION

This chapter provides an introduction to the Environmental Technology Evaluation Center (EvTEC) process for verifying the performance of commercial-ready ultra-urban stormwater control technology.

The relative merits of traditional stormwater control measures in the context of existing developed communities have become an important issue. The impending EPA stormwater Phase II regulations, the safety of public water supplies, and the threat to endangered aquatic species have intensified interest in identifying innovative approaches for protecting source and receiving water quality. Also, additional drivers for innovation are the implementation of the Coastal Zone Act Reauthorization Amendments (CZARA), Section 6217g, Nonpoint Source Management Measures by CZM Coastal Zone States, and the desire of many local watershed committees to improve and restore degraded streams as part of their watershed restoration priorities submitted to EPA by states as requested by the Clean Water Action Plan. Comprehensive stormwater regulations, space limitations, hardened infrastructure, high urban land values, limitations of traditional BMPs, and the increase in urban runoff pollutant loads over the last decade have spurred the development of a new class of products and technologies. These non-traditional methods of capturing runoff contaminants before they reach surface and groundwater have been labeled in many circles as "ultra-urban" technologies.

Ultra-urban stormwater technologies have an appeal that historical methods of stormwater management do not have in developed areas. They are particularly suited to retrofit applications in the normal course of urban renewal, community revitalization, and redevelopment, as well as new urban development. These engineered devices are typically structural and are made on a production line in a factory. They may be designed to handle a range of pollutant and water quantity conditions in highly urbanized areas. Some ultra-urban stormwater controls have small footprints and may be literally dropped into the urban infrastructure or integrated into the streetscape of both private and public sector property. Others may be installed beneath parking lots and garages or on rooftops. Still others are designed to remove pollutants before they are flushed into urban runoff collection systems.

The introduction of these recent innovations has raised several concerns among experts in the water quality field. For example, how should the performance of these devices be verified over a range of flow rates? Traditional performance monitoring and sampling protocols may not be

WSDOT is constructing a test site that receives urban stormwater from a heavily traveled section of interstate highway within the City of Seattle. WSDOT is also required to treat its stormwater runoff under various state and federal laws. Therefore, WSDOT is a potential consumer of ultra-urban technologies and requires an evaluation process of these new products. In this partnership, WSDOT will provide the test site and EvTEC will facilitate the evaluation process.

## 1.2 ROLES AND RESPONSIBILITIES

The Ultra-Urban Stormwater Evaluation project is more complex than most EvTEC projects because the number of participants is greater. This section discusses the roles and responsibilities of the different participants while **Figure 1-1** illustrates the relationships.

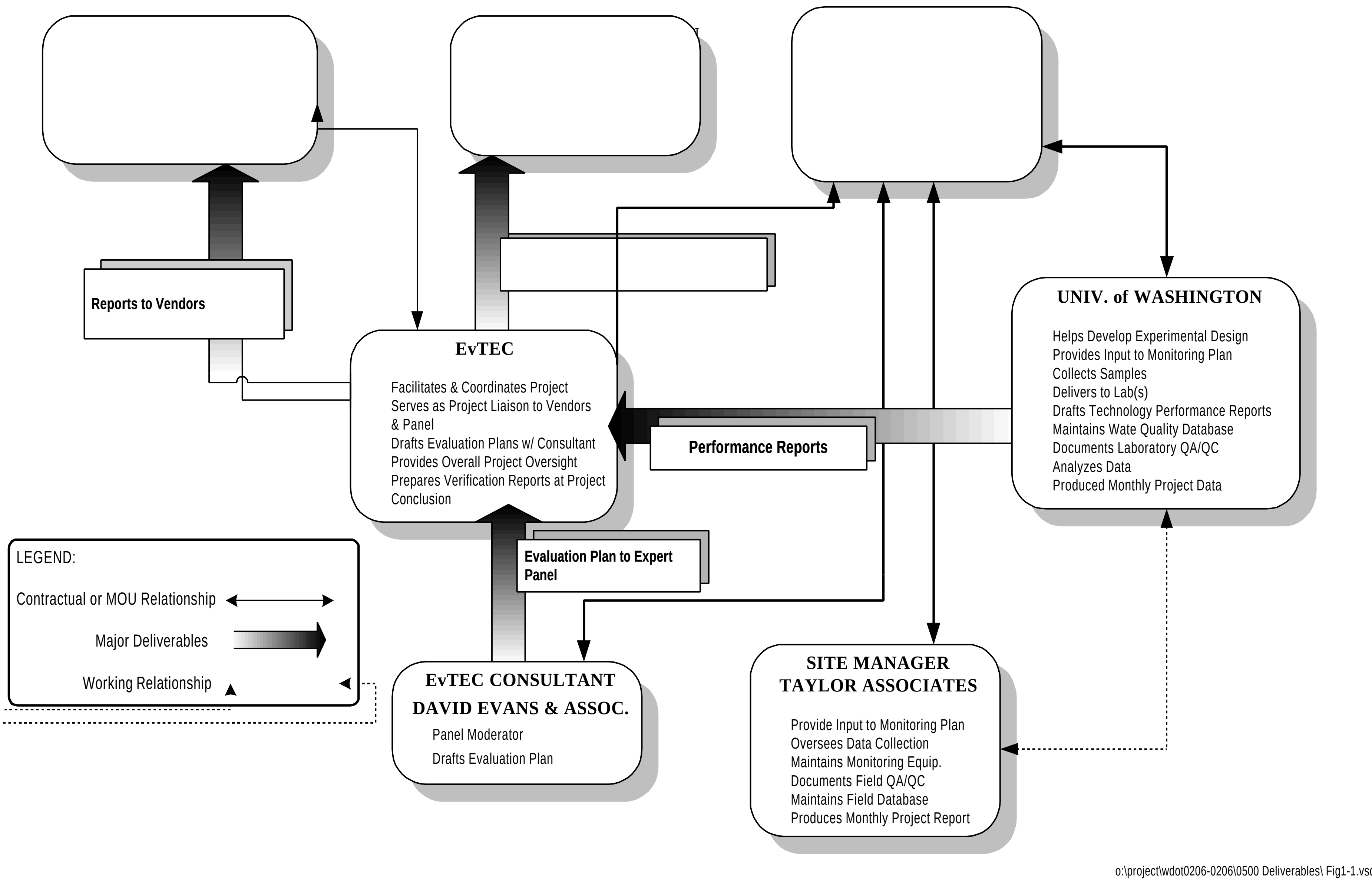
**EvTEC:** EvTEC is the lead agency for the project and provides overall project oversight. They maintain the integrity of the evaluation process to ensure that it is accurate and comprehensive. They facilitate and coordinate the project by acting as the liaison between the Vendors and the Panel. Along with the Consultant, EvTEC drafts the Evaluation Plan and prepares the Final Report. They have contractual relationships or Memoranda of Understanding (MOU) with WSDOT, the Consultant, and the Vendors.

**WSDOT:** WSDOT will design, build, operate, and own the test facility at the Lake Union site. They oversee installation of all equipment and are responsible for security at the site. As a potential purchaser of these technologies, WSDOT will also help select the evaluation parameters. They will also review the Evaluation Plan and Reports. They will hire and supervise the Site Manager and the University of Washington staff (UW). They have contractual relationships or MOUs with EvTEC, the Consultant, the UW, and the Site Manager.

**Technical Evaluation Panel:** The members of the Technical Evaluation Panel (Panel) are all volunteers whose expenses for traveling to and from Panel meetings are covered by EvTEC. They are responsible for identifying and selecting the technical protocols and parameters in the Evaluation Plan. They define the issues and review the Evaluation Plan and Verification Reports. They have no contractual relationships with EvTEC or the Vendors, but have signed pledges of confidentiality with EvTEC and the vendors.

**Vendors:** The Vendors supply the technologies to be tested and describe them. They review the Evaluation Plan and provide comments to EvTEC on the Plan and Verification Reports. They also install their equipment at the site. They provide financial assistance for the project and have contractual relationships with EvTEC.

the field database. They prepare monthly Project Status reports summarizing data collection and compliance with field QA/QC procedures. They coordinate the distribution of


Reports to Vendors
EvTEC
Facilitates & Coordinates Project
Serves as Project Liaison to Vendors & Panel
Drafts Evaluation Plans w/ Consultant
Provides Overall Project Oversight
Prepares Verification Reports at Project Conclusion
UNIV. of WASHINGTON
Helps Develop Experimental Design
Provides Input to Monitoring Plan
Collects Samples
Delivers to Lab(s)
Drafts Technology Performance Reports
Maintains Wate Quality Database
Documents Laboratory QA/QC
Analyzes Data
Produced Monthly Project Data
Performance Reports
Evaluation Plan to Expert Panel
LEGEND:
Contractual or MOU Relationship
Major Deliverables
Working Relationship
EvTEC CONSULTANT
DAVID EVANS & ASSOC.
Panel Moderator
Drafts Evaluation Plan
SITE MANAGER
TAYLOR ASSOCIATES
Provide Input to Monitoring Plan
Oversees Data Collection
Maintains Monitoring Equip.
Documents Field QA/QC
Maintains Field Database
Produces Monthly Project Report
o:\project\wdot0206-0206\0500 Deliverables\ Fig1-1.vsd

the report in conjunction with the monthly Project Data Report. They coordinate the monthly project review meeting. They are hired by WSDOT and have contractual relationships with WSDOT.

**University of Washington:** WSDOT contracts with the UW for data collection and analysis services. Professor David Stensel of the UW Civil and Environmental Engineering Department is the lead professor and will be the Data Analysis Manager. Several engineering graduate students will participate in the data analysis and be members of the Field Team. The UW staff help develop the experimental design and the Evaluation Plan. They collect samples and deliver to the testing laboratory. They perform the settling velocity and particle size distribution analyses. They maintain the water quality database and they prepare the monthly Project Data Reports. They also prepare the technology performance reports on the technologies for use by EvTEC. The UW has a contractual relationship with WSDOT.

## 1.3 OBJECTIVES OF THE EVALUATION

There are four basic objectives for the evaluation of ultra-urban stormwater technologies:

1. Verify the performance claimed by the vendor.
2. Evaluate the technology as a Best Management Practice for treating urban stormwater.
3. Evaluate the technology in a treatment train with other BMPs.
4. Evaluate the operation and maintenance costs, safety and other operational issues.

### 1.3.1 VERIFICATION

One of the primary objectives of the EvTEC process is to verify vendors' performance claims. The specific piece of equipment tested shall be selected and supplied by the vendor based on the hydraulic criteria of the test site. The equipment shall be an off-the-shelf unit available for purchase by potential users and shall not be modified except as normally required for adaptation to a particular site. The Evaluation Plan will design a test that fairly and objectively measures the claimed performance of the technology under the design conditions. Each technology is evaluated separately because the design and performance criteria vary between technologies. While some technologies have similar attributes, most are unique. For this reason, a comparison between technologies would be difficult. Therefore, the Evaluation Plan focuses on verifying claims rather than comparing technologies.

mandated by federal and state water pollution control laws and rules. In most cases, those regulations require the use of BMPs to control non-point source pollution in stormwater.

The following definition of BMPs is from the Washington Administrative Code for the Waste Discharge General Permit Program (WAC 173-226-030(3)) and is typical of such definitions around the country.

> "Best Management Practices" or "BMPs" mean schedules of activities, prohibitions of practices, maintenance of procedures, and other management practices, to prevent or reduce the pollution of the waters of the state. BMPs also include treatment requirements, operating procedures, and practices to control plant site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage.

The Evaluation Plan will test the ability of the technology to prevent or reduce a broad spectrum of pollutants commonly occurring in urban stormwater. The Panel shall recommend the appropriate pollutants and WSDOT shall concur with the selection. The Evaluation Plan shall fairly and objectively test each technology.

### 1.3.3 TREATMENT TRAIN USE

The Panel expressed interest in evaluating the technologies in a treatment train. By combining the technologies that remove a specific spectrum of pollutant with other approved BMPs, users may obtain higher pollutant removal efficiencies.

However, there are several problems with evaluating treatment train use of the technologies. First, the choice of technologies available in a treatment train extends beyond those being tested in this Evaluation Plan. For example, there are no grass-lined swales upstream or downstream of the facility. Second, there are a substantial number of combinations using these technologies and other BMPs. The costs of testing these different combinations are prohibitive. Finally, the physical layout of the site would exclude many BMPs from being tested as part of a treatment train. Despite these limitations, some vendors may have technologies that operate in a treatment train that could be installed at the test facility. The Panel, EvTEC and WSDOT are open to the possible testing of such a treatment train.

As an alternative to direct testing of the technologies in a series of treatment trains, the Evaluation Report for each technology will draw some conclusions on the potential use of each technology in different types of treatment trains. The conclusions will be based on the test results and the collective expertise of the Panel. The various assumptions necessary to support the conclusions

The Evaluation Plan shall include data gathering of O&M and LCC information. To the extent available, this information shall be supplied by the vendors. The Site Manager will document maintenance activities as they occur during the test in the field notebook. Since the test period is likely to be only a single season, it is unlikely that any of the technologies will reach or exceed their designated "economic" lifespan. The Verification Report will extrapolate the O&M and LCC issues based on the data gathered during the test period and the vendor's maintenance recommendations.

## 1.4 ENVIRONMENTAL ISSUES AND CONCERNS

The Panel was asked to identify any issues and concern relative to the evaluation from a federal, state, or local environmental agency, user community, private sector, or academia standpoint. The Panel identified the following environmental issues. The listing of the issues and concerns is presented in an approximate order in which they were discussed.

***Technology Accommodation at the Site:***

- Use of the technology in a treatment train
- Minimum flow requirements for each technology
- Pre-Treatment requirements for each technology

***Experimental Design:***

- Data needs in light of prior vendor test records
- Sampling and instrumentation issues
  - Sample representativeness
  - Mechanics of sampling; equipment location and operation
- Sample collection frequency and duration
  - Minimum number of storm events
  - Event-driven
  - First flush versus later storms
  - Continuous versus discrete sampling
- Range of target pollutants and concomitant analytics
  - What pollutant loading and characteristics are required to meet vendor, WSDOT, and other needs/requirements

- Schedules
- Equipment and manpower requirements

***Defining Project Objectives:***

- Scope of verification
- Transferability of data
- Usefulness of existing guidance for stormwater technology testing
- Regulatory compliance requirements

These issues are addressed in more detail in Chapter 3, The Monitoring Plan.

## 1.5 WSDOT USE OF EVALUATION RESULTS

WSDOT will use the test results to add new stormwater treatment technologies to its standard highway runoff manual. WSDOT will include technologies in the manual that: 1) are effective at removing highway runoff pollutants, 2) are cost effective based on performance operation life and maintenance requirements, and 3) meet water quality goals. Ideally, BMP operation life should be more than 20 years. WSDOT will not evaluate "experimental BMPs" for ultra-urban applications against quantitative BMP standards since these standards do not presently exist. Rather, the evaluation of technologies will be based on the performance of off-the-shelf units provided by the vendors for the test facility. The Final Report will review each unit's performance against the stormwater discharge targets specified in the industrial stormwater general permit issued by the Washington State Department of Ecology (Ecology). Also, the Report will examine the performance against the design criteria guidelines in Ecology's *Stormwater Manual* for the Puget Sound Basin. The resulting performance data must be accepted by the Ecology before the technology is approved for purchase and included in the WSDOT *Highway Runoff Manual*.

# 2.0 DESCRIPTION OF SITE AND TEST FACILITY

## 2.1 HYDROLOGY AND DRAINAGE AREA

The Lake Union Test Facility is located in the State Route 5 (SR 5) right of way beneath the Lake Union Ship Canal Bridge's north approach structure, in the vicinity of mile post 168.9 (**Figure 2-1)**. The site's drainage basin extends from the crest of the Ship Canal Bridge north to Northeast 55th Street (see **Photograph 2-1**). The basin lies within the right of way boundaries. The WSDOT stormwater collection system for the basin is separate from the City of Seattle's stormwater system for the adjoining neighborhoods and streets. The land use within the basin is interstate highway and associated vegetated landscaping.

The drainage basin encompasses approximately 31.6 acres, with 22.7 acres of pavement and 8.9 acres of roadside landscaping. The drainage plan for the basin is shown in **Appendix B**. A 30-inch storm sewer pipe drains the basin, including all SR 5 northbound, southbound, and express lanes, and on- and off-ramps. Catch basins provide the only stormwater treatment within the drainage basin: there are 15 Type 1 catch basins and 53 Type 2 catch basins. The catch basin specifications are shown in **Appendix B**.

**Table 2-1** illustrates the modeled flow rates for the 30-inch stormwater pipe that provides water to the test facility under the bridge. Actual flow rates were measured in the manhole located immediately upstream of the test facility beginning in June 1999. The actual rates and volumes measured were substantially higher than predicted by either the Santa Barbara Urban Hydrograph (SBUH) or the King County Runoff Time Series (KCRTS) methods. Possible explanations for the discrepancies were examined but no definitive answer was forthcoming. **Appendix C** summarizes the results of the investigation.

Based on the flows measured in the field, numerous storms with peak flows between 2 and 4 cubic feet per second (cfs) are expected. Storms of 20 cfs peak flow are expected twice per year and storms exceeding 50 cfs are considered rare (50-100-year storms).

**Table 2-1: Modeled Flow Rates**

| Calculated Peak Flow Rates | 24 Hour Precip. | SBUH "WaterWorks" | KCRTS |
|---|---|---|---|
| Smallest Peak Flow analyzed | 1.28"/ 6 Month | 5.89 cfs/ 6 Month Return Period | 7.55 cfs/ 1Year Return Period |
| 2 Year Return Period | 2.00" | 10.35 cfs | 10.81 cfs |

Figure 2-1:  Vicinity Map - SR 5, Lake Union Ship Canal Bridge Project Site

Photograph 2-1:  SR 5, 45th Avenue NE Looking South.  Lower Drainage Basin

## 2.2 TEST FACILITY DESIGN

The Lake Union Ship Canal Bridge on SR 5 spans 100 plus feet above the Ship Canal. WSDOT owns the land underneath the bridge on the north side of the canal and this is where the test facility is located. An existing 30-inch storm sewer transports the stormwater runoff from the drainage basin described above to a discharge point on the Ship Canal.

**Figure 2-2** illustrates a plan view layout for the test facility. The test facility will be a fenced enclosure around the asphalt test pads. **Figure 2-2** illustrates the elevations and layout for the four test bays. The bays are numbered 1 through 4 going west to east. The bays are situated between the support columns for the bridge. The site is constrained by the footings that support the bridge piers. These footings must have a minimal amount of cover to protect them.

The elevations are shown for the footings, finished grade of the asphalt, the invert of the pipes to each bay, and the catch basins draining the site. The drop between the pipe and the asphalt varies between 4 to 5 feet for bays 1, 2, and 4. Some of the drop between the pipe and the test unit will be consumed by the mixing chamber and the flow measuring device. To accommodate taller stormwater technologies such as swirl concentrators, WSDOT will install a vault in bay 2 into which these taller technologies will be lowered. Bay 3 has a step down that lowers its elevation by another 2 feet.

## 2.3 FLOW SPLITTING DESIGN

Appendix B contains detailed plan drawings illustrating how flows will be routed to the site. A new segment of 30-inch storm sewer will be constructed above the existing storm sewer parallel to Pasadena Place N.E. The new pipes will be at a flatter grade to convey flow to the research site and provide treatment at a shallower depth. A modified manhole will divert flows from the 30-inch pipe into a 24-inch storm sewer that conveys stormwater to the facility. The modified manhole contains a steel trough for conveying flows up to 25 cfs. The trough is removable so that flow to the Lake Union test facility may be stopped.

The 24-inch storm sewer branch will convey stormwater flow to the site. A Type 1 flow splitter at the site will split the flow between two 18-inch pipes, which are subsequently split again downstream using a Type 2 flow splitter (see Figure B-7, Appendix B). The Type 1 flow splitter consists of a vertical vane weir in the flow stream that splits the flow evenly between the two 18-inch downstream pipes. The Type 2 flow splitters contain an adjustable vertical vane in the flow stream capable of splitting flow in any ratio, depending upon vane position. Downstream of the two Type 2 flow splitters, flow is discharged into 12-inch PVC pipes to each of the test bays

Figure 2-2: Plan View of Test Facility

The adjustable vertical vein weirs in the Type 2 flow splitters allow flexibility in determining the flow ranges over which a technology is evaluated. Adjustments to the vertical vanes can occur between storms to target specific flow ranges at each technology. In the event that an insufficient number of samples are being collected at the higher end of the operational flow rates of the technologies, flow can be diverted to only some of the technologies during selected storms. The technologies that would be taken off-line would be rotated.

The effectiveness of the flow-splitting adjustments will be monitored continuously by flow meters at the inlet to each technology to ensure that the flow is proportioned as accurately as possible. In addition, water quality at the inlet to each technology will be monitored to assess the effectiveness of the flow splitters in delivering uniform pollutant loads to each test bay.

A more detailed flow splitting strategy will be developed once the operational flow ranges and test bay locations of the technologies have been determined.

## 2.4 EXISTING WATER QUALITY

Water quality data were collected during the 1999/2000 wet season to provide a baseline characterization of flow at the site and to identify potential sources of additional water to the site. As part of this effort, water quality samples for laboratory analysis were collected during one baseflow and two storm events and will be collected during one additional storm event this wet season. A total of six samples have been collected and analyzed to date. The samples were analyzed for the parameters selected by the EvTEC Panel (Table 3-1, Section 3.3) with the exception of settling velocity, PSD, and trash and debris. In addition to the EvTEC parameters, the samples were analyzed for fluoride, ammonia-N, methylene blue active substances (MBAS), chlorine residual, and fecal coliforms to identify potential non-stormwater sources contributing to the drainage basin flows. Temperature and pH were measured *insitu* using a YSI 6820 water quality monitoring sonde. Samples were analyzed by an EPA certified laboratory. The University of Washington is conducting a PSD and settling velocity study discussed later in this section.

Samples were collected from a manhole located upstream of the facility test site using an ISCO 6700 automated sampler. The 3/8-inch Teflon sample intake line was located approximately one inch above the invert of the 30-inch concrete pipe behind a three-inch dam installed to create backwater for the YSI sonde. The sample intake line was approximately 15 feet long and had a vertical rise of approximately 10 feet. Grab samples were collected by manually activating the automated sampler. Due to the location of the manhole (i.e., on a construction site) and space constraints within the manhole, purely automated sampling, which would allow for time-paced grab sample collection or flow-paced composite sampling, was not possible.

**Table 2.2** summarizes the results of the water quality sampling to date. When available, the ranges of average values for highway runoff reported in the literature (Driscoll et al., 1990 as cited in Barrett et al., 1995) are presented for comparison.

Baseline water quality data indicate that most of the pollutant concentrations at the site, for which there are data to compare, are at the low end of the range of values cited for highway runoff. It is important to note that comparison values found in the literature are averages; thus, they do not reflect observed maximum or minimum concentrations. Results of the baseline water quality study indicate that total copper, lead, and zinc, TSS, TS, TKN, TP, COD, and TOC concentrations are less than the midpoint of their respective concentration ranges cited in the literature. Oil and Grease, nitrate-nitrite nitrogen, and specific conductivity spanned the range of concentrations cited in the literature. Total magnesium and turbidity were higher than the average values given in the literature but this may be due to that only a single value (versus a range) was available for comparison. Some ammonia-N and fecal coliform concentrations were greater than those reported in the literature. Possible reasons are discussed below in the paragraph discussing screening for non-stormwater sources.

The ratio of dissolved metals to total metals varied by metal. The average percent of the total metal concentration represented by dissolved metals (for samples with reportable results) were as follows (with associated standard deviations): 94 ± 13 % for magnesium, 34 ± 16% for copper, 7 ± 9% for lead, and 53 ± 20% for zinc. The total suspended solids concentration represented an average of 43 ± 10% of the total solids concentration in each sample.

Baseline water quality data collected so far indicates that several pollutants are frequently near or below reporting limits: dissolved and total cadmium and dissolved lead. These parameters will be considered for removal from the EvTEC parameter list. Oil and grease and TPH are also frequently below reportable levels. However, this may be an effect of the sampling technique, using an automated sampler with Teflon tubing. Once the test facility is operational, oil and grease and TPH will be collected using manual grabs.

Baseline water quality data are also being evaluated to screen for non-stormwater sources of water to the facility. To accomplish this, fluoride, ammonia-N, MBAS (surfactant test), chlorine residual, and fecal coliforms were added to the EvTEC parameter list. Chlorine residuals were barely detectable and fluoride concentrations were significantly below the level for treated water (1 mg/$\ell$). This indicated that it is unlikely that significant amounts of treated water are reaching the site. Surfactants (i.e., MBAS), an indicator of detergents, were detected in storm flows. Research has indicated that the presence of detergents indicates that a portion of the flow is probably from a contaminated non-stormwater source (Lalor et al., 1993). The ammonia-N and

# Table 2-2: Baseline Water Quality Data

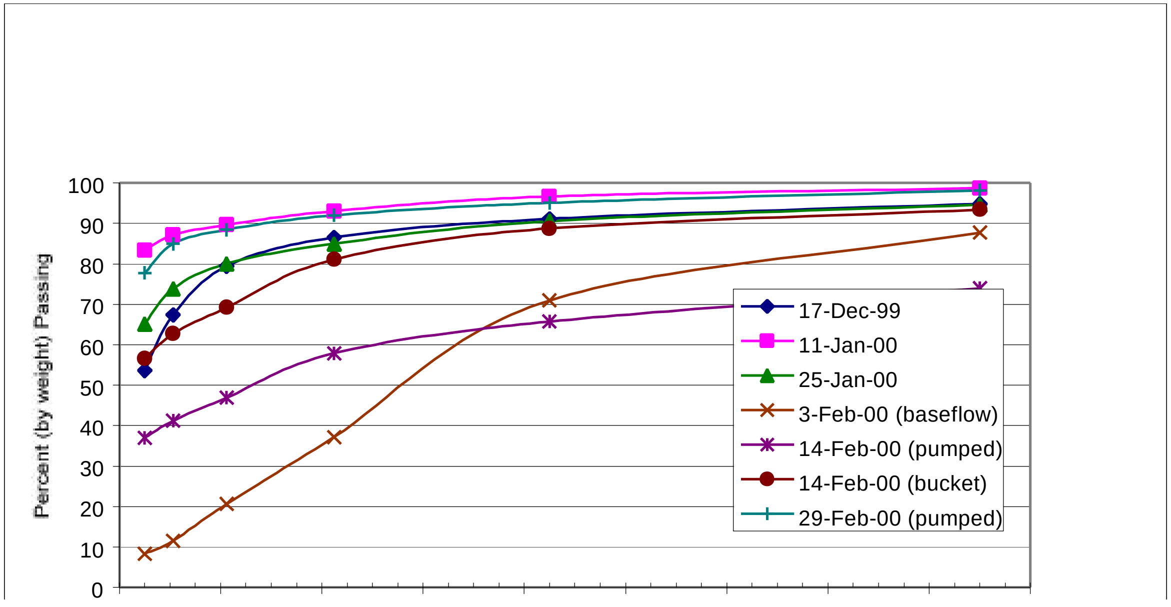
| Parameter | Unit | Unit | 9/10/99 8:50 | 10/7/99 23:15 | 10/8/99 6:30 | 12/17/00 10:45 | 12/17/00 10:50 | 12/17/00 10:55 | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Sample Date - Time | | | | | | |
| Collection Method | | | automated grab | | automated grab | bucket grab | | automated grab (dup.) | |
| **LABORATORY DATA** | | | | | | | | | |
| Total Metals | | | | | | | | | |
| Calcium | Mg/L | 0.250 | **47.5** | **51.0** | **10.3** | **11.6** | **12.1** | **11.5** | |
| Magnesium | Mg/L | 0.100 | **21.9** | **12.9** | **1.28** | **1.51** | **2.05** | **1.83** | 1.062 |
| Cadmium | Mg/L | 0.00100 | ND | ND | ND | ND | ND | ND | ND - 0.04 |
| Copper | Mg/L | 0.00100 | **0.0189** | **0.0208** | **0.0323** | **0.0356** | **0.0308** | **0.0265** | 0.022 - 7.033 |
| Lead | Mg/L | 0.00100 | ND | **0.0031** | **0.0112** | **0.0300** | **0.0238** | **0.0174** | 0.073 - 1.78 |
| Zinc | Mg/L | 0.0100 | **0.0317** | **0.105** | **0.109** | **0.169** | **0.139** | **0.112** | 0.056 - 0.929 |
| Dissolved Metals | | | | | | | | | |
| Magnesium | Mg/L | 0.500 | **23.7** | **12.7** | **0.948** | **1.53** | **1.71** | **1.82** | |
| Cadmium | Mg/L | 0.00100 | ND | ND | ND | ND | ND | ND | |
| Copper | Mg/L | 0.00100 | **0.00250** | **0.01180** | **0.01540** | **0.00844** | **0.00897** | **0.00944** | |
| Lead | Mg/L | 0.00100 | ND | ND | **0.00105** | **0.00130** | **0.00137** | **0.00145** | |
| Zinc | Mg/L | 0.0100 | **0.0252** | **0.0700** | **0.0694** | **0.0523** | **0.0479** | **0.0459** | |
| Conventional Parameters | | | | | | | | | |
| PH | pH units | | **8.45** | **7.30** | **7.35** | **7.49** | **7.42** | **7.51** | 7.1 - 7.2 |
| Total Suspended Solids ( TSS) | Mg/L | 5.0 | ND | **36** [1] | **42** [1] | **120** | **70** | **60** | 45 - 798 |
| Total Solids (TS) | Mg/L | 10 | **310** | **340** [1] | **110** [1] | **180** | **140** | **120** | 437 - 1147 |
| Total Solids (repeated by lab) | Mg/L | 10 | **290** [1] | | | | | | |
| Total Volatile Solids ( TVS) | % by weight | 10 | **26** | **14** [1] | ND [1] | **21** | **13** | **23** | |
| Settleable Solids | Ml/L | 0.10 | ND | ND | ND | **3.0** | **2.0** | **1.5** | |
| Oil & Grease (HEM) | Mg/L | 5.00 | ND | ND | **6.36** | ND | **8.29** | **19.6** | 2.7 - 27 |
| Petrol. Oil Hydrocarbons ( SGT-HEM) | Mg/L | 5.00 | ND | ND | ND | ND | ND | **6.69** | |
| Turbidity | NTU | 1.00 | ND | **22.6** | **37.7** | **83.1** | **65.7** | **58.9** | 19 |
| *Fluoride* | Mg/L | 0.100 | **0.127** | **0.174** | **0.100** | ND | ND | ND | |
| *Ammonia-Nitrogen* | mg/L as N | 0.100 | ND | **1.79** | **1.02** | **0.912** | **0.863** | **0.977** | 0.07 - 0.22 |
| TKN | mg/L as N | 1.00 | ND | **3.44** | **1.65** | **1.54** | ND | **1.71** | 0.335 - 55.0 |
| Nitrate/Nitrite-Nitrogen | ug/L as N | 10.0 | **775** | **1540** | **671** | **332** | **371** | **353** | 150 - 1636 |
| Orthophosphate-phosphorus | Mg/L | 0.00200 | **0.0665** | **0.166** | **0.0633** | **0.0103** | **0.0103** | **0.0108** | |

| | | | Sample Date - Time | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | Unit | Unit | **9/10/99 8:50** | **10/7/99 23:15** | **10/8/99 6:30** | **12/17/00 10:45** | **12/17/00 10:50** | **12/17/00 10:55** | |
| Total Phosphorus ( TP) | Mg/L | 0.00500 | **0.0719** | **0.372** | **0.118** | **0.139** | **0.0819** | **0.083** | 0.113 - 0.998 |
| Chemical Oxygen Demand (COD) | Mg/L | 10.0 | **14.1** | **84.3** | **38.6** | **102** | **92.5** | **67.5** | 14.7 - 272 |
| Total Organic Carbon (TOC) | Mg/L | 1.00 | **4.51** | **20.8** | **9.08** | **7.02** | **5.27** | **5.22** | 24 - 77 |
| *Methylene Blue Active Substances (MBAS)* | Mg/L | 0.0500 | ND | **1.11** | **0.544** | **0.210** | **0.171** | **0.199** | |
| Hardness | mg eq. CaCO3/L | 1.00 | **209** | **180** | **30.9** | **35.2** | **38.7** | **36.3** | |
| *Chlorine Residual* | Mg/L | 0.0200 | **0.0201** | ND | ND | ND | **0.0224** | **0.0206** | |
| Anions by EPA Method 300.0 | | | | | | | | | |
| Chloride | Mg/L | 0.400 | **13.6** | **12.5** | **1.31** | **1.05** | **1.07** | **1.06** | 4.63 - 1344 |
| Physical Parameters | | | | | | | | | |
| *Specific Conductivity* | uS/cm | 1.00 | **448** | **419** | **79.8** | **71.5** | **75.2** | **76.2** | 337 - 500 |
| Microbiological Parameters | | | | | | | | | |
| *Fecal Coliforms* | MPN/100 ml | 2.0 | **23** | **900** | **900** | [redacted] | **240** | **240** | 50 - 590 |
| | | | | | | | | | |
| **FIELD DATA** | | | | | | | | | |
| Temperature | C | | 16.0 | 16.6 | 13.9 | 8.4 | 8.5 | 8.5 | |
| PH | pH units | | 8.5 | 8.0 | 7.1 | 7.6 | 7.5 | 7.5 | |
| Nitrate | mg/L as N | | 13.7 | 140 | 575 | 26.4 | 28.5 | 30.3 | |
| | | | | | | | | | |
| **FLOW INFORMATION** | | | | | | | | | |
| Flow | Cfs | | < 0.1 (estimate) | | | 0.60 | 0.73 | 0.64 | |
| Rainfall during hour of sampling | in/hr | | 0 | 0.01 | 0.05 | 0.09 | 0.09 | 0.09 | |
| Rain in 2-hour period prior to sampling | In | | 0 | 0.03 | 0.19 | 0.11 | 0.11 | 0.11 | |
| Segment of storm | | | baseflow | onset | falling limb | rising limb | | rising limb | |

**Bolded** results indicate those detected in the sample. ND indicates parameter not detected.
*Italics* indicate parameters that are being analyzed as part of the baseline water quality study. They will not be evaluated as part of the stormwater technology monitoring program.
[1] These samples were reanalyzed outside of the EPA recommended holding time due to laboratory error.

non-stormwater source (e.g., sewage) may be reaching the site. This would not affect the suitability of the site for evaluating the ultra-urban technologies since pollutant concentrations are within the range of non-highway stormwater runoff.

The University of Washington is conducting studies on the particle size distribution (PSD) and settling velocity characteristics of flow at the site. PSD and settling velocity samples are being collected using a manual grab method during the 1999/2000 wet season. Five storm samples and one base flow sample have been analyzed for PSD to date. **Figure 2-3** illustrates the particle size distribution results for all sampling events. For the five storm samples, the smallest size fraction (< 25 micron) accounted for at least 50% (by weight) of the TSS in all cases except for the pumped sample on February 14, 2000. For the January 11, 2000 sample, the <25 micron fraction accounted for greater than 80% of the TSS. In contrast, the base flow sample exhibited a more uniform distribution of particle size. Standard deviations for the PSD analysis of replicate samples were generally good for the storm events, calculated as less than 12% of the average in all cases except the February 14, 2000 pumped sample (standard deviation up to 20% of average value). Standard deviations for the base flow sample were considerably higher (between 14% and 79% of the average value). For clarity, PSD standard deviations are not shown on **Figure 2-3**. For a more detailed discussion of the PSD sampling collection method, analytical method, and results refer to the Preliminary Draft PSD Report for the EvTEC Storm Water Technology Evaluation Project (Appendix D). Settling velocity results are not yet available.



the automated sampler and analyzed by an analytical laboratory. The TSS concentrations of the automated samples, 70 mg/ℓ and 60 mg/ℓ, were less than the TSS concentration of the bucket grab sample, 120 mg/ℓ (Table 3.2). On February 14, 2000, the University of Washington collected samples using both the manual bucket grab and automated sampler methods. Their analyses indicated that the pumped samples had a higher average TSS concentration (154 mg/ℓL) than the manual grab samples (96 mg/ℓ). In addition, the pumped samples had a higher fraction of large particles than the bucket grab samples (Appendix D). Results for the sampling from these two dates are at odds. Factors that may affect the comparability of the two methods are the potential for the automated sampler to sample bedload and the potential of the bucket method not to sample the entire water column. Once the facility is constructed, these factors will no longer influence sample collection since both automated and grab samples will be collected from a mixing chamber instead of a subsurface pipe. It is important to be aware of the potential for bias using automated samplers. However, there is no practical alternative to using automated samplers to meet the project goals. A limitation of this study will be the bias introduced by the use of automated samplers. Once the facility is constructed, a comparison of automated samples from the mixing chamber and samples collected from the spigot on the mixing chamber should provide a better understanding of the potential for automated sampler bias in this study.

Although not quantifiably measured, trash and debris have been observed. Debris occasionally lodges on the monitoring hardware located in the manhole. Visual inspections have shown a small plastic lemon shaped container, a plastic sandwich bag, plastic flagging, a cigarette butt, and organic debris (primarily leaves).

The results of the initial water quality testing are discussed in more detail in Appendix D.

## 2.5 TRAFFIC AND MAINTENANCE

SR 5 from the crest of the Ship Canal Bridge to Northeast 55th Street has an average daily traffic of 233,400 vehicles. Regular maintenance procedures in the area are included in **Table 2-3**.

**Table 2-3:**
**Ship Canal Drainage Area Maintenance Procedures**

| Type of Maintenance | Description | Frequency |
|---|---|---|
| Street Sweeping | Mechanical street cleaner, sweepings treated and recycled or disposed of properly based on contaminant concentrations. More effective on urban streets than highways. | Depends on the accumulation of leaves, paper, or other debris. Cleaning may be as frequent as twice a month to prevent clogging of the drainage system. Occurs about every two months in this area. |
| Catch Basin Pumping | Inlets, catch basins, and man-holes inspected and cleaned out with a vacuum truck. Decant water disposed of at decant station or approved sanitary sewer, solids treated and recycled or disposed of by approved methods. | Annually, at a minimum. In urban traffic areas, cleaned after the first storm at the beginning of autumn with a rainfall volume greater than 1 inch, removing much of the pollutant load deposited during the dry months. |
| Drain Flushing | Bridge drains are flushed to remove sediments from the piping. | Drains are flushed once each summer. In winter, they are flushed about every two months. |
| Ditches | Ditches are inspected to identify sediment accumulations, localized erosion, and other problems. Open ditches are maintained to the line, grade, depth, and cross section to which they were constructed. | Ditches are inspected twice each year, and cleaned at least annually. |
| Snow and Ice Control | Removal or treatment of snow and ice on regularly traveled state routes to ensure the safety of the traveling public. | Removal of snow as it accumulates using plows. Application of roadway abrasives and/or chemical deicers to ice or compact snow that cannot be removed. |

References: WSDOT Highway Runoff Manual, Chapter 7; Pat Moylan, Bridges.

# 3.0 MONITORING PLAN

## 3.1 INTRODUCTION

As stated in Chapter 1.0, there are four main objectives for performance evaluation:

- Verify the performance claims of the vendor;
- Evaluate technologies for use as BMPs;
- Evaluate the technology as a component of a treatment train; and,
- Evaluate operational issues, such as life-cycle costs.

The vendors will install the urban stormwater treatment technology devices at the Lake Union Test Facility. The devices will be stand-alone, off-the-shelf units and will be sized by the vendors to handle the range of stormwater flows expected. A stated goal of the Panel for the evaluation program is to determine the treatment performance of the technologies for at least 20 storm events (or until convergence of the data are achieved) for up to a one-year period for a wide range of pollutant parameters over the operating flow rate of the technology.

The Evaluation Plan focuses on verifying the performance claims of the vendor by evaluating the relationship between pollutant removal efficiency, inflow pollutant concentrations, and operating flow rates over the operating flow rate of the technology. The performance of any treatment technology must be related to a key design or operating parameter that affects the process performance when changed. For many physical separation processes, a key operating parameter is the hydraulic application rate (operating flow) in cubic feet per second (cfs). As the operating flow rate through a treatment unit increases, residence time decreases and, consequently, design treatment efficiency may decrease. In addition, removal efficiency may be affected by the influent concentration of the pollutant parameter.

## 3.2 SAMPLING STRATEGY

The goal of sample collection is to provide data to verify a technology's performance over the operating flow rate of the technology. Due to the characteristics of some of the parameters, three different sampling strategies will be used to evaluate the technologies. The majority of the pollutants will be evaluated using an automated time-paced sampling strategy. Oil and grease and total petroleum hydrocarbons will be sampled using a manual grab sampling strategy due to the 3 $\ell$ sample volume requirement and the propensity of these pollutants to adhere to the Teflon tubing and polyethylene containers used for automated sample collection. Settling velocity and

### 3.2.1 Automated Time-paced Sampling Strategy

#### *3.2.1.1 Introduction*

Technology performance will be evaluated by determining the relationship between pollutant removal efficiency, inflow pollutant concentrations, and operating flow rates over the operating flow range of the technology. This approach presents two challenges to sampling strategy design:

1. Given that there is detention and perhaps some degree of mixing within a stormwater technology, how are inflow and outflow samples paired to determine removal efficiencies for a given flow rate?
2. Using available technology, how are adequate sample volumes for analysis to be collected at various flow rates throughout the storm?

The sampling strategy described below addresses both of these issues for the majority of the pollutants, beginning with objectives and a method summary, followed by a more detailed description of the field method. The design rationale section discusses how the challenges listed above are addressed, as well as additional benefits and limitations of the sampling strategy. This sampling strategy was developed in response to EvTEC panel comments on the EvTEC Draft Evaluation Plan (1998).

#### *3.2.1.2 Objective*

The objective of the sampling strategy is to determine the pollutant removal efficiency of the technologies with an approximate equal number of sampling events at flow rates in the range of 25 to 50%, 50 to 75%, 75 to 100%, and 100 to 125% of the technologies rated capacity.

Removal efficiency will be calculated for each water quality parameter at a given inflow rate as follows:

Removal Efficiency = $(C_i - C_o)/(C_i)*100$

Where $C_i$ = inflow concentration of parameter

$C_o$ = outflow concentration of parameter

Sampling results will provide removal efficiencies as a function of inflow rate and concentration for each parameter evaluated.

#### *3.2.1.3 Method Summary*

1. Within the Storm Sampling Period, the variation of storm inflow will be less than or equal to 20%.

2. The Storm Sampling Period will be greater than or equal to 8 times the Estimated Detention Time for each technology. The Estimated Detention Time will be determined prior to the initiation of sampling based on the average anticipated flow rate to a technology and the technology's storage capacity. This "estimated" detention time is used only as an approximation to determine the length of the minimum Storm Sampling Period. It is not used to calculate removal efficiencies.

**Figure 3-1** graphically illustrates Storm Sampling Period Criteria for a hypothetical storm hydrograph.

To implement this strategy, flow monitoring and water quality sampling stations will be established upstream and downstream of each stormwater technology being evaluated. During a storm event, samples will be collected on a predetermined time interval (i.e., time-pacing) using automated samplers. The samplers will contain 24 one-liter bottles. Each bottle will collect a time-paced composite sample during the "bottle time interval" (**Figure 3-2**). Within each bottle, four subsamples will be collected at one-fourth the bottle time interval, the "subsample time interval" (**Figure 3-2**). For example, if the bottle interval is one hour, the subsample interval will be 15 minutes. Upstream and downstream stations will be programmed to collect samples simultaneously. Storm sampling will only occur after a specified antecedent dry period has occurred, and the automated samplers will be enabled by a rise in water level at the inflow.

At the end of the storm event or at the completion of the sampling program (an estimated 8 to 16 hours), whichever comes first, upstream (inflow) hydrograph will be reviewed and "Storm Sampling Periods" for each stormwater technology will be determined using the criteria presented above. Storm Sampling Periods will consist of multiple bottle time intervals and will start at the beginning of a bottle time interval and end at the completion of a bottle time interval. All samples assigned to a Storm Sampling Period will be flow-weight composited using the inflow flow data for the inflow samples and the outflow flow data for the outflow samples. A hypothetical example of determining how samples will be combined and flow-weighted is shown in **Figure 3-3.**

For each technology, a pre-monitoring study will be conducted to determine hydrologic characteristics specific to the site and each technology. The study will consist of a review of the inflow and outflow hydrographs for several storms at each technology. From these data, the initial Sample Bottle Interval for each technology will be determined. The Sample Bottle Interval will be determined to maximize the number of Sampling Storm Periods within a storm event. This

Figure 3-1:  Storm Sampling Period Criteria

Figure 3-2: Nomenclature

Figure 3-3:  Example

#### *3.2.1.4 Design Rationale*

The objective of this sampling strategy is to evaluate the removal efficiencies of the technologies over a range of flow rates. As discussed in the Introduction, this objective presents two challenges in terms of sampling logistics. The following paragraphs describe the manner in which each challenge is addressed.

**Given that detention and mixing occur within a stormwater technology, how are inflow and outflow samples paired to determine removal efficiencies at a given flow rate?**

**Solution:** Storm sampling periods are longer than eight times the estimated detention time of the stormwater technology. The effects of detention within the technology are minimized to, at most, 25% of the Storm Sampling Period. For example, assume the Estimated Detention Time of the facility is 15 minutes. If the same 2-hour period (8 x 15 min.) is sampled at both the inflow and the outflow, the maximum error that could be introduced is: the first 15 minutes of outflow does not represent the inflow during the 2-hour period, and the last 15 minutes of inflow does not correspond to outflow within the 2-hour period. Thus, the error is minimized to 25% of the 2-hour period (15min+15min= 0.5 hr).

**Using available technology, how are adequate sample volumes for analysis to be collected at various flows throughout a storm?**

**Solution:** Flows throughout a storm will be sampled on a time-paced basis and collected in 24 1-ℓ bottles. Compositing several bottles into Storm Sampling Periods will increase the volume of sample available for analysis.

To more accurately characterize the concentrations of storm flow passing through the station during the bottle time interval, four time-paced 250 mℓ subsamples will be collected in each bottle at the subsample time interval (i.e., one fourth of the bottle time interval). It would be preferable to flow-weight (vs. time-weight) the four subsamples; however, it is not possible to collect adequate sample volumes while flow-pacing the subsamples and time-pacing the samples. However, time-pacing the subsamples will have only a slight effect on the bottle concentration. For bottles to be selected for analysis, the subsamples must meet the criteria of having been collected when the flow rate did not vary by more than 20% (and likely less if the bottle is to be composited). The less variation in the flow rate between the subsample time intervals, the more the time-pacing method imitates the flow-pacing method.

There are additional benefits to this stormwater technology sampling strategy:

- More than one data point can be collected during a storm event (i.e., more than one Storm Sampling Period can occur within a storm).
- The strategy of and criteria for combining samples into Storm Sampling Periods is well suited to Pacific Northwest precipitation events, which tend not to exhibit a defined storm peak (as shown in the idealized, hypothetical hydrograph shown in Figures 3-1, 3-2, and 3-3), but tend to have several smaller peaks over a longer time period.

Limitations to this stormwater technology sampling strategy include:

- The time-paced sampling strategy is not designed to sample an entire storm. Event Mean Concentrations (EMCs) cannot be calculated unless, by chance, the sampling program for a given storm event spans the entire storm event and all samples are selected for analysis. The sampling strategy is also not designed to specifically evaluate the technologies during distinct "first flush" conditions.
- Removal efficiencies are calculated on the basis of inflow and outflow concentrations and are not equivalent to removal efficiencies calculated by load (concentration x volume) in some other study types.
- As previously discussed, time-paced subsamples are a biased estimate of the average concentration in the flow during a bottle time interval.
- As previously discussed, creating Storm Sampling Periods greater than eight times the Estimated Detention Time minimizes error introduced by detention, but does not eliminate it.
- The effectiveness of the sampling strategy is somewhat determined by the type and number of parameters to be evaluated. The type and number of parameters will determine the sample volume required for analysis. The volume required for analysis will be a factor in determining sample bottle time intervals. Sample bottle time intervals (and thus duration of the storm sampled) are reduced in proportion to sample volume required. A practical sample volume of 1.8 liters is suggested for collection using the time-paced sampling strategy while still obtaining several Storm Sampling Periods within a storm. Pollutant parameters will be tiered into primary, secondary, and tertiary parameters. Secondary and tertiary parameters will only be analyzed when there is adequate sample volume available.

### 3.2.2 Manual Grab Sampling Strategy

Oil and grease, total petroleum hydrocarbons, settling velocity and PSD samples cannot be collected using the automatic time-paced method mentioned above due to the large sample volumes required. In addition, oil and grease and total petroleum hydrocarbons tend to adhere to to detention time. During a storm event, a grab sample will be manually collected from the inflow and the inflow rate recorded. Using the curve, the estimated detention time of the technology at the measured inflow rate will be determined. After the estimated detention time has elapsed, a sample will be collected from the outflow of the technology. These samples will be paired to determine removal efficiency at the inflow rate during the detention period. The flow data will be reviewed and the variation in the inflow rate and the average inflow rate over the period will be determined. If the variation in inflow during the detention period is greater than 20%, the sample will not be analyzed. The average inflow rate will be used to characterize the inflow rate of the sample.

Due to the labor intensiveness of this strategy, samples for these parameters will only be collected during two to four storms. During each storm, field staff will attempt to collect at least three samples over a range of inflow rates at each technology during each storm. The range of inflow rates to be targeted will be determined once the technologies have been selected. Flow ranges will be selected based on the operating flow rates of the technology. For example, targeted flow ranges may be 25 to 50%, 50 to 80%, 80 to 100%, and 120 to 150% of the technology's design flow. Due to the labor intensiveness of the PSD and settling velocity analyses, the University of Washington is currently evaluating the data collection needs for the PSD and settling velocity evaluations. The number of samples collected at each technology during a storm and the number of storm sampled for PSD and settling velocity may be reduced based on their evaluation.

The benefit of the manual grab strategy is that it allows for large volume of sample to be collected at various flow rates for each technology within a storm. The limitation to this strategy is that it assumes a uniform inflow pollutant concentration between the collection of the inflow and outflow samples (i.e., the estimated detention time). When evaluating the results of the manual grab samples, a review of the continuous turbidity measurements may indicate the uniformness of the inflow pollutant concentration during the manual grab sample collection period.

### 3.2.3 Trash and Debris Sampling Strategy

Trash and debris captured by each technology will be evaluated qualitatively over time during the test period. After each sampled storm event, each technology will be visually inspected, and the volume of trash and debris will be estimated. The material deposited (e.g., litter, vegetative matter, sediment) and the approximate size of debris will be recorded. Removal of trash debris, and sediment will follow the vendor's recommendations for the technology.

After the technology monitoring phase of the project is complete, the amount and type of material in the technologies will be quantified. Depending on the volume of material, either the entire

## 3.3 POLLUTANT PARAMETERS

### 3.3.1 Parameters Selected for Evaluation

The selection of pollutant parameters is related to the project objectives. For verification of vendors' claims, a relatively narrow set of parameters would be sufficient since most of the technologies are aimed at a particular pollutant category. However, agencies like WSDOT are required to remove or reduce a broader range of parameters under their federal water quality permits. To evaluate the BMP potential of the different technologies, the selected parameters include those typically regulated by federal and state agencies, even though the vendors may not make any specific claim to affect these parameters. The Verification Reports will distinguish between verifying vendors' claims and evaluating BMP performance.

The Panel ranked a long list of candidate pollutants for this study, and the top 29 pollutants selected are listed in **Table 3-1**. The parameters in bold typeface are the minimum required by WSDOT.

**Table 3-1:**
**Ultra-Urban Stormwater Pollutant Parameters Selected by the EvTEC Panel**

| Particulate Matter | General Characteristics | Organic Material | Metals | Nutrients |
|---|---|---|---|---|
| Turbidity<br>**Total Suspended Solids (TSS)**<br>Volatile Suspended Solids (VSS)<br>**Total Solids (TS)**<br>Settleable Solids<br>**Settling Velocity**<br>**Particle Size Distribution (PSD)**<br>**Trash and debris** | pH<br>Temperature<br>Chloride<br>Hardness | **Oil and Grease**<br>**Total Petroleum Hydrocarbon (TPH)**<br>Total Chemical Oxygen Demand (COD)<br>Total Organic Carbon (TOC) | **Total Cadmium (Cd)**<br>**Soluble Cadmium**<br>**Total Copper (Cu)**<br>**Soluble Copper**<br>**Total Lead (Pb)**<br>**Soluble lead**<br>**Total Zinc (Zn)**<br>**Soluble Zinc**<br>Soluble Magnesium (Mg) | **Total Kjeldhal Nitrogen (TKN)**<br>**Nitrate/Nitrite (Nox)**<br>**Total Phosphorous (TP)**<br>**Soluble Phosphorous (SP)** |

The ability of each technology to remove such conventional pollutants as TSS will be tested. Settleable solids measurements will be a principal parameter for assessing the treatment performance possible for TSS removal. The treatment unit effluent solids concentrations will be compared to the solids concentration that would remain in the liquid after quiescent settling conditions. Since it may not be possible to remove 100% of the suspended solids, the TSS test will be a good indicator of treatment technology limitations caused by the solids characteristics.

samples may be useful for relating fundamental characteristics of the particulates to the process mechanisms. However, the ability to obtain such data will depend on the TSS concentrations in the stormwater runoff. The University of Washington is currently evaluating settling velocity analysis methods.

Particle size distribution is another useful fundamental parameter that can be related to the removal mechanisms for the treatment technologies. Recent research shows a strong correlation between particle size and metals transport in urban runoff. Smaller size particles may not be within the treatment ability of certain processes and thus can help explain process limitations. Such information would provide a useful means of estimating process performance for other stormwater runoff at different sites with different particulate characteristics. Based on the results of the PSD analyses, variable aperture sieves will be used to obtain samples from certain size groups. It is anticipated that several of these PSD samples from the stormwater influent will be tested to determine their pollutant-bearing characteristics. Standard particle counts (mg/ℓ) will also be performed. PSD will be correlated with particle counts for different storm event intervals.

In addition to particulate matter, the Panel indicated that measurement of soluble organics, metals, and nutrient compounds is important to developing a better understanding of removal mechanisms and processes in the field even if a given technology is not intended to remove or reduce certain pollutant concentrations. The organics, metals, and nutrient parameters include both total and dissolved measurements. Evaluation of these parameters may indicate that non-dissolved portions of organic material (e.g., COD, TOC), metals, and nutrients (organic nitrogen, phosphorus) are removed in proportion to TSS removal. Some parameters normally considered as standard stormwater parameters were not identified by the Panel as vital to this study of ultra-urban runoff treatment. These include 5-day biological oxygen demand (BOD5) and ammonium-nitrogen (NH3-N).

The Panel deemed litter and floating debris removal as important to this performance evaluation. Litter, floating debris, and large settleable solids may not be readily sampled by continuous monitoring equipment or grab sampling techniques. Trash and debris captured by each technology will be evaluated qualitatively and quantitatively as described in Section 3.2.3.

Table 3-2 provides a summary of the sampling and analytical methods that will be used for analysis of each parameter. Sample preservation of oil and grease and TPH will occur in the field. All other preservatives will be added at the laboratory. Holding times indicated in Table 3-2 are after preservatives have been added.

### 3.2.2 Primary, Secondary, and Tertiary Parameters

analyses. The tertiary parameters are COD and TOC. An additional 100 mℓ is required for these analyses. Table 3-2 indicates the tier of each parameter collected using the automated sampling method and the volume requirements for each parameter tier.

In summary, when the composited volume of a storm sampling period is between 1,650 mℓ and 2,049 mℓ, only primary parameters will be analyzed for. When the composited volume is between 2,050 mℓ and 2,149 mℓ, primary and secondary parameters will be analyzed for. When the composited volume is greater than 2,150 mℓ, the sample will be analyzed for primary, secondary, and tertiary parameters.

To minimize sample volume requirements, laboratory QA/QC will not be project-specific. QA/QC analyses may be performed on project samples if there is adequate volume. Otherwise QA/QC analyses will be performed on non-project samples in the same batch. The exception to this will be the oil and grease and TPH samples. Since volume of manual grab samples is not a concern matrix spike (MS) and matrix spike duplicate (MSD) will be run on project samples.

### 3.3.3 Revision of Parameter List

The parameter list may be revised prior to or during the course of the study. Some analytical processes may not be available through the contract laboratory. For example, the lab WSDOT is currently contracted with does not analyze for volatile suspended solids or soluble phosphorus. Currently, total volatile solids and orthophosphate phosphorus are being measured instead. Some parameters may not be present in high enough concentrations to warrant continued sampling and analysis. Other parameters may be redundant. For example, it may not be necessary to sample for both COD and TOC to characterize the overall organic removal. Similarly, not all the metals may need to be analyzed. Under the sampling strategy described in Section 3.2, temperature will not be measured.

An initial revision of the parameter list will be made based on the water quality data collected during the 1999/2000 Wet Season (see Section 2.4, Existing Water Quality). After the water quality data have been collected (one more storm has yet to be sampled), recommendations will be made to the Panel on parameters that could be removed from the list. Recommendations will be based on parameters below or near their reporting limits that would not provide meaningful removal efficiencies. It is suggested that parameter concentrations in the inflow be at least three times its reporting limit for it to be included on the parameter list. Based on the water quality samples taken so far, total and dissolved cadmium and dissolved lead may be candidates for removal from the parameter list.

## Table 3-2: Summary of Pollutant Parameter Sampling and Analytical Methods

| Parameter | Container | Primary, Secondary, or Tertiary | Minimum Sample Size (mℓ) | Sample Method | Preservation | Holding Time | Reporting Limit and Units | EPA/SM Method | To Be Performed By |
|---|---|---|---|---|---|---|---|---|---|
| **Particulate Matter:** | | | | | | | | | |
| Turbidity | poly | P | * | A, F | cool, 4° C | 48 hr. | 1 NTU | EPA 180.1 | Anal. Lab |
| Total Suspended Solids (TSS) | poly | P | * | A | cool, 4° C | 7 days | 5 mg/ℓ | EPA 160.2 | Anal. Lab |
| Total Solids (TS) | poly | P | * | A | cool, 4° C | 7 days | 10 mg/ℓ | EPA 160.3 | Anal. Lab |
| Volatile Suspended Solids (VSS) | poly | P | * | A | | ? | 10 mg/ℓ | EPA 160.4 | Anal. Lab |
| Settleable Solids | poly | P | * | A | cool, 4° C | 2 days | 0.1 mℓ/ℓ | EPA 160.5 | Anal. Lab |
| Settling Velocity | poly | -- | 12ℓ | G | cool, 4° C | 7 days | -- | TBD | UW |
| Particle Size Distribution (PSD) | poly | -- | 12ℓ | G | cool, 4° C | 7 days | -- | TBD | UW |
| Trash and Debris | -- | -- | -- | -- | | -- | -- | TBD | UW |
| **General Parameters:** | | | | | | | | | |
| PH | poly | P | * | A | cool, 4° C | 24 hrs. | -- | EPA 150.1 | Anal. Lab |
| Chloride | poly | P | * | A | cool, 4° C | 28 days | 0.4 mg/ℓ | EPA 300.0 | Anal. Lab |
| Hardness | poly (Ca and Mg samples used) | P | to be determined by Ca and Mg ICP | A | see Ca and Mg | -- | 1.00 mg eq. $CaCO_3$/ℓ | SM 2340B | Anal. Lab |
| Calcium, Ca | poly | P | * | A | $HNO_3$ to pH<2 | 6 months | 0.250 mg/ℓ | EPA 200.7 | Anal. Lab |
| Temperature | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **Organic Material:** | | | | | | | | | |
| oil and grease | glass | -- | 1,500 mℓ (includes MS/ MSD QA) | G | HCl to pH <2, cool, 4° C | 28 days | 5 mg/ℓ | EPA 1664 | Anal. Lab |
| Total Petroleum Hydrocarbons (TPH) | glass | -- | 1,500 mℓ (includes MS/ MSD QA) | G | HCl to pH <2, cool, 4° C | 28 days | 5 mg/ℓ | EPA 1664 | Anal. Lab |
| Total Chemical Oxygen Demand (COD) | poly | T | * | A | $H_2SO_4$ to ph<2, cool, 4°C | 28 days | 10 mg/ℓ | EPA 410.4 | Anal. Lab |
| Total Organic Carbon (TOC) | poly | T | * | A | $H_2SO_4$ to ph <2 cool, 4° C, store in dark | 28 days | 1.0 mg/ℓ | EPA 415.1 | Anal. Lab |

## Table 3-2: Continued

| Parameter | Container | Primary, Secondary, or Tertiary | Minimum Sample Size (mℓ) | Sample Method | Preservation | Holding Time | Reporting Limit and Units | EPA/SM Method | To Be Performed By |
|---|---|---|---|---|---|---|---|---|---|
| **Metals:** | | | | | | | | | |
| Total cadmium ( Cd) | poly | P | * | A | $HNO_3$ to ph <2, cool, 4°C | 6 months | 1 µg/ℓ | EPA 200.8 | Anal. Lab |
| Soluble cadmium ( Cd) | poly | P | * | A | filter, $HNO_3$ to ph <2, cool 4° C | 6 months | 1 µg/ℓ | EPA 200.8 | Anal. Lab |
| Total copper (Cu) | poly | P | * | A | $HNO_3$ to ph <2, cool, 4°C | 6 months | 1 µg/ℓ | EPA 200.8 | Anal. Lab |
| Soluble copper (Cu) | poly | P | * | A | filter, $HNO_3$ to ph <2, cool 4° C | 6 months | 1 µg/ℓ | EPA 200.8 | Anal. Lab |
| Total lead ( Pb) | poly | P | * | A | $HNO_3$ to ph <2, cool, 4°C | 6 months | 1 µg/ℓ | EPA 200.8 | Anal. Lab |
| Soluble lead ( Pb) | poly | P | * | A | filter, $HNO_3$ to ph <2, cool 4°C | 6 months | 1 µg/ℓ | EPA 200.8 | Anal. Lab |
| Total zinc ( Zn) | poly | P | * | A | $HNO_3$ to ph <2, cool, 4°C | 6 months | 10 µg/ℓ | EPA 200.8 | Anal. Lab |
| Soluble zinc ( Zn) | poly | P | * | A | filter, $HNO_3$ to ph <2, ool 4° C | 6 months | 10 µg/ℓ | EPA 200.8 | Anal. Lab |
| Magnesium (Mg) | poly | P | * | A | $HNO_3$ to ph <2, cool, 4°C | 6 months | 500 µg/ℓ | EPA 200.7 | Anal. Lab |
| **Nutrients:** | | | | | | | | | |
| Total Kjeldahl Nitrogen (TKN) | poly | S | * | A | $H_2SO_4$ to ph <2 cool, 4° C | 28 days | 1 mg/ℓ as N | EPA 351.3 | Anal. Lab |
| Nitrate /nitrite (NOx) | poly | S | * | A | $H_2SO_4$ to ph <2, cool, 4°C | 28 days | 10 mg/ℓ as N | EPA 353.2 | Anal. Lab |
| Total phosphorus (TP) | poly | S | * | A | $H_2SO_4$ to ph <2, cool, 4°C | 28 days | 5 µg/ℓ | EPA 365.2 | Anal. Lab |
| Soluble phosphorus (SP) | poly | S | * | A | Filter, cool, 4° C | 48 hr | 2 µg/ℓ | EPA 365.2 | Anal. Lab |

Notes:
A = Automated discrete or manually composited sample. G = Manual grab sample. F = Field Measurement
* = Sample Volume Requirements. Primary parameters require 1,650 mℓ. Secondary parameters require 400 mℓ. Territory parameters require 100mℓ.

## 3.4 NUMBER OF SAMPLES

The number of data points needed to develop a statistically acceptable correlation between the performance parameter and an independent parameter will be determined using a statistical procedure that determines the sample size needed to determine a mean performance value with a certain level of confidence. The method yields the number of samples necessary to state that the mean value of the removal efficiency is at a certain confidence level within a certain range. For example we might say that at a given flow rate we are 95% confident that the average process removal efficiency is 80% plus or minus 10%. Equations to determine the number of samples to achieve this goal depend on the following:

- Confidence level
- Desired range around the mean
- Variance of the data set

The variance is site specific and can be affected by variations in the stormwater characteristics, sampling and analytical error, operating conditions, and treatment technology characteristics. The variance must be known to determine the actual number of samples that need to be evaluated in each flow range for each technology. In order to compute the variances, tests from the field are necessary. In the meantime, the variance and the necessary sample size may be estimated. If a variance of 20% is assumed, then approximately 30 data points would provide a reasonable correlation. With less variance a sample size of approximately 20 data points is possible. Thus, it is reasonable to assert that 20 to 30 data points per range of operating flows are needed to develop a correlation between parameter removal efficiency and operating flow rate. Operating flow ranges appropriate for each technology will be determined once the technologies have been selected. A range of operating flows may, for example, include flows between 0.5 to 1 cfs.

To obtain the 20 to 30 data points per range of operating flows, 15 to 20 storm events may be necessary. Because of the limited distribution of high flows, it may not be possible to collect 20 to 30 data points for operating flows in the higher ranges.

The Data Analysis Manager will be responsible for statistically evaluating the data and determining the number of samples necessary to achieve statistically significant results and updating this number, as necessary, during the project.

## 3.5 STORM EVENT CRITERIA

The EvTEC criteria for a rainfall event for this project are as follows:

At the Lakemont facility in the City of Bellevue (located approximately 13 miles east of the WSDOT facility site), 25 storm events met the EvTEC criteria from October 1995 to April 1996.

## 3.6 RAINFALL MEASUREMENT

Rainfall will be measured and continuously recorded at the top of the Atmospheric Sciences (ATG) building at the University of Washington located one-half mile (3,000 feet) due east of the project location. The University of Washington maintains this rain gage. The precipitation gage data are available, real time, through the Internet at http://www.atmos.washington.edu/cgi-bin/list_uw.cgi.

## 3.7 FLOW MEASUREMENT

Flow rates will be continuously monitored upstream and downstream of each treatment unit. Based on the flow splitting design (see Section 2.3), the flow measurement equipment will function over a range of approximately 0.1 to 5 cfs.

Two methods for monitoring flow are being evaluated. The preferred method is to use a low flow area-velocity meter in conjunction with a necked down section of the inflow and outflow pipe. The low flow area-velocity meter calculates flow by measuring depth and velocity. The low flow area-velocity meter requires depths greater than one inch to measure flow. The necked down section of the pipe would be designed such that the one-inch depth corresponds to a minimum acceptable level for flow rate detection. The second method is to use an H flume in conjunction with a bubbler line or pressure transducer to measure water elevation.

The flow monitoring station design has not been finalized. More information on the facility layout (i.e., the size and placement of the technologies) is necessary to determine the rise and run available for flow monitoring installations and sampling chambers. Additionally, the potential of the technologies to create backwater conditions will need to be determined prior to final flow monitoring station design.

WSDOT and the Site Manager will oversee the selection and design of the flow monitoring system. The Site Manager will be responsible for its calibration and maintenance.

## 3.8 INFLUENT AND EFFLUENT SAMPLING

As discussed in Section 3.2 Sampling Strategy, both automated discrete samples and manual grab samples will be collected upstream and downstream of each technology. In addition, turbidity will

Figure 3-4:  Mixing Chamber Design

(e.g., turbidimeter, sampling line) when there is little or no flow. A mechanical mixer, activated by a level sensor in the chamber, will ensure that the chamber is well mixed. A spigot on the side of the chamber will allow for grab sample collection, and the automated sampler intake line will be located in the chamber. The turbidimeter is an on-line type similar to those used in wastewater treatment systems. A pump will direct water from the sampling chamber through the turbidimeter.

The sampling chamber is designed to provide a mixed zone from which to collect the samples. Automated samplers will be used to collect the samples for the majority of the pollutant parameters. In comparison to manual sampling, automated sampling allows for the collection of more data with fewer personnel at the site. The use of automated samplers provides consistency and reliability in data collection and is more cost effective than manual sampling. However, automated samplers do introduce some bias during sample collection. Particles or debris larger than 3/8 inch (the diameter of the automated sampler intake line) are not collected, and there is concern that automatic samplers do not representatively collect larger particles less than 3/8 inch. The latter bias will be minimized to the extent possible by minimizing the rise and the run of the sampler intake lines. Although automated samplers introduce bias, they are a necessary component of the monitoring program. The results of the PSD samples, manual grab samples collected from the spigot on the side of the mixing chamber, can be used to assess the bias of the automated samplers.

## 3.9 SAMPLING PROCEDURE

Sample collection is scheduled to begin 6 weeks after installation of the technologies. The initial goal for sample collection is to conduct automated water quality sampling at the site during twenty storms, and, during four of the storm events, to collect manual grab samples. As discussed in Section 3.4, Number of Samples, the Data Analysis Manager will review the data as the project progresses to determine the number of samples needed to achieve statistically significant results. Based on these results, the number of storms to be sampled or flow rates targeted within storms may be adjusted during the course of the study.

The Site Manager will monitor antecedent dry conditions and upcoming storm predictions via the Internet and determine whether to respond to, or "target", an approaching storm. Once a storm has been targeted, the Field Team will proceed to the site to perform a pre-storm visit. The purpose of the pre-storm visit is to verify that the Type 2 flow splitters are set correctly, ensure that the monitoring equipment is operational, set-up additional samplers to collect field duplicates if necessary, and to set the samplers to begin automated sampling in response to a rise in water level at the inflow pipe to each technology. Tasks performed during the pre-storm visit will be each sampler holds 24 - 1 ℓ bottles. Each bottle will collect a time-paced composite sample during the "bottle time interval". Within each bottle, four subsamples (250 mℓ) will be collected at one-fourth the bottle time interval, the "subsample time interval". The automated sampling program will be complete once the 24 sample bottles have been filled (i.e., 24-bottle sample interval).

Once the sampler program is complete or flow has returned to base flow conditions (whichever comes first), a post-storm visit will be conducted by the Field Team. Due to the 24-hour maximum holding time for some of the parameters, the post-storm visit will occur within 16 hours of the onset of the sampling event. Rainfall data will be reviewed by the Site Manager to ensure that the Storm Criteria have been met. If the minimum rainfall amount has not occurred, the samples will be discarded and the samplers reset. If the Storm Criteria are met, flow data will be downloaded, and samples will be retrieved from the automated sampler. Lids will be placed on the 24 samples, ice placed in the sampler base, and the base containing the samples will be delivered to the location where the samples will be composited. Each technology will be visually inspected from above ground and the presence of an oily sheen and trash and debris will be recorded. Tasks performed during the post-storm visit will be summarized on a Post-Storm Site Visit Sheet and included in the Field Notebook.

Immediately after the post-storm visit is conducted, the Field Team, under the direction of the Site Manager, will composite the samples for delivery to the analytical laboratory. For each technology, the upstream (inflow) hydrograph data will be reviewed and "Storm Sampling Periods" will be determined using the criteria presented in Section 3.2.1. Sample bottles to be combined as part of a Storm Sampling Period will be flow-weight composited using the inflow flow data for the inflow samples and the outflow flow data for the outflow samples. Samples will be composited into poly bottles provided by the Analytical Laboratory. Samples will be labeled and a Chain of Custody Form completed. Chain of Custody Forms will be kept in the Field Notebook. Samples will be placed on ice and delivered to the Analytical Laboratory.

During the four storms during which manual grab samples for PSD, settling velocity, oil and grease, and total petroleum hydrocarbons are to be collected, the sample procedure will be the same as above with the addition that members of the Field Team will be at the site during the storm to collect the grab samples. Designated members of the Field Team will proceed to the site when paged that the automated sampling has begun. Field Team members will have a list of targeted flow ranges under which to collect samples at each technology. The objective of the manual grab sample collection is to collect at least three pairs (i.e., inflow and outflow) of samples representing different flow rates from each technology during the storm. At a given technology, each technology throughout the storm. All samples will be labeled. After the storm event, inflow data will be reviewed that inflow did not vary by more than 20% during the detention period. Manual grab activities will be recorded on a Manual Grab Data Sheet and included in the Field Notebook. Oil and grease and total petroleum hydrocarbon samples will be delivered to the Analytical Laboratory along with the composited automated samples. The PSD and settling velocity samples will be delivered to the University of Washington for analysis.

## 3.10 SITE OPERATIONS

The Site Manager will oversee the site operations of the monitoring facility and will be responsible for the following:

- Calibration of flow and water quality monitoring equipment.
- Routine maintenance of monitoring equipment to assure that it will work promptly and properly for each storm event.
- Overseeing the maintenance of the technologies (see further discussion below).
- Training and oversight of the University of Washington Field Team.
- Preparation of monthly Project Status Reports summarizing the number of samples collected at each technology in each flow range to date, site conditions, maintenance activities, and field QA/QC activities.
- Distribute the monthly Project Status Reports in conjunction with the Project Data Reports.
- Coordinate monthly project review meeting.

The vendors will be responsible for the installation of their respective technology at the test facility. Due to the one-year monitoring period, it is not anticipated that maintenance of the technologies will be required. If maintenance is required, it will be performed in accordance with vendor's written or verbal instructions or by the vendor. All maintenance performed shall be documented in the Field Notebook. The vendors will not be permitted to perform maintenance tasks independently once monitoring has begun.

## 3.11 DATA MANAGEMENT

There are four sources of data for this project: electronic field data (i.e., flow, turbidity, and rainfall data), the Field Notebook, analytical laboratory data, and UW laboratory data. The data management procedures for each source of data are presented below.

Flow and turbidity data will be downloaded after each storm event by the Field Team during the

Water quality results from the analytical laboratory will be sent directly to both the Data Analysis Manager and the Site Manager. The Data Analysis Manager will be responsible for overseeing the maintenance of the water quality database by the University of Washington. The water quality database will be backed-up weekly.

Under the oversight of the Data Analysis Manager, results of the PSD and settling velocity analyses performed by the University of Washington will be entered directly into the water quality database maintained by the University of Washington.

## 3.12 DATA EVALUATION AND REPORTING – MONITORING PLAN

There are two data evaluation tasks directly related to the monitoring plan: an initial review of data to ensure compliance with field and laboratory QA/QC requirements and the evaluation of the pollutant removal efficiencies of each technology. Additional data evaluation and reporting required to meet the objectives of the overall project will be performed by EvTEC as part of the Verification Reports.

Initial data review for conformance with field and laboratory QA/QC performance will be conducted. The Site Manager is responsible for reviewing field data for compliance with field QA/QC requirements. This includes reviewing flow, turbidity, and rainfall data to ensure the equipment is operating properly. The Site Manager will also review laboratory data to ensure that the all samples were analyzed for the correct parameters and to evaluate the results of field duplicates and field blanks. The Site Manager will prepare monthly Project Status Reports summarizing the number of samples collected at each technology in each flow range to date, site conditions, maintenance activities, and field QA/QC activities. The Laboratory QA Manager and the Data Analysis Manager will be responsible for reviewing the laboratory data for conformance with laboratory QA/QC requirements.

The University of Washington, under the supervision of the Data Analysis Manager, will evaluate the relationship between pollutant removal efficiency, operating flow rates, and inflow pollutant concentrations. Data will be evaluated to document a technology's performance relative to the stormwater inflow rates and influent concentrations. Performance results for similar flow rates for different storm events will be evaluated to determine if trends in effluent concentrations or percent removal efficiencies of the pollutant parameters are related to flow rate. The evaluation will include development of an understanding of removal mechanisms for the technologies and relating those to stormwater characteristics and treatment performance. The removal efficiencies of technologies that depend on gravity separation to settleable solids and particle size distribution data will be evaluated. Particle size distribution analysis may also explain treatment technology

The University of Washington, under the supervision of the Data Analysis Manager, will produce monthly Project Data Reports including the most recent data analyzed, summary of data analyzed to date, compliance with lab QA/QC criteria, and the current number of samples to be collected based on the ongoing statistical data evaluation. The monthly Project Data Reports will be transferred to the Site Manager for distribution with the monthly Project Status Reports. At the conclusion of the monitoring program, the University of Washington will summarize their findings in Technology Performance Reports, one for each technology, to be submitted to EvTEC.

## 3.13 HEALTH AND SAFETY

The site will need to be accessed during inclement weather, day or night, for maintaining monitoring equipment and collecting samples. At a minimum, the following personal protective equipment shall be worn during all fieldwork, including equipment deployment and maintenance and sample collection: eye protection, steel-toed boots, hard hat, and safety vest. Two members of the Field Team will be present during field work performed during non-daylight hours.

Although technologies are to be located above ground, installation and maintenance of monitoring equipment and the maintenance of flow splitters at the test facility may require work in confined spaces. Because of the potential risks presented by these working conditions, field personnel participating in confined space entry work will be trained in hazard communication, personal protective equipment, confined space attendance, and confined space entry procedures.

## 3.14 GENERAL TASKS REQUIRED TO IMPLEMENT THE MONITORING PLAN

The following general areas of work are required to implement the Monitoring Plan presented in Chapter 3 of the Evaluation Plan. The implementation schedule is uncertain at this time; however, most of the project development activities will be concurrent or at least overlap. Some of the pre-project preparations could be undertaken and completed immediately. The actual task schedule will be refined after the proposed plan is reviewed and accepted by the EvTEC Panel, the vendors, and WSDOT.

- Review and revise this Evaluation Plan in conformance with EvTEC Panel and vendors' recommendations.
- Complete characterization of pollutant loads in the flows to the Lake Union site.
- Provide instruction to vendors for sizing equipment and vendors provide "final" treatment technology performance claims.
- Finalize site layout including technology placement and monitoring station design.
- Determine flow ranges over which a technology will be evaluated and finalize flow splitting strategy.

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